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REPORT

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GAS WASHING OF FRACTURE SURFACES BY EXPLOSIVE DETONATION PRODUCTS

A.J. Bedford

Approved for Public Release

MARCH, 1977

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ABSTRACT

Experiments have been carried out to study the nature of features produced on fracture surfaces after washing with the gaseous products of detonation of a high explosive. White-etching, essentially untempered martensite layers are produced. A porous outer layer indicative of melting may form, masking features of the original fracture surface. It is concluded that most fragments from a detonated body are ejected before these effects can occur.

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16. ABSTRACT (if this is security classified, the announcement of this report will be similarly classified):

Experiments have been carried out to study the nature of features produced on fracture surfaces after washing with the gaseous products of detonation of a high explosive. White-etching, essentially untempered martensite layers are produced. A porous outer layer indicative of melting may form, masking features of the original fracture surface. It is concluded that most fragments from a detonated body are ejected before these effects can occur.

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GAS WASHING OF FRACTURE SURFACES

BY EXPLOSIVE DETONATION PRODUCTS

INTRODUCTION

During investigations of fracture surfaces of explosively formed steel fragments, structures are sometimes observed which appear to be the result of surface melting or of some sort of smearing or burnishing so that the sharp fracture features are substantially obliterated. Examples of such features are shown in the scanning electron micrographs in Fig. 1.

This phenomenon is usually attributed to "gas washing" by the high-velocity high-temperature product gases of the detonated explosive. Cross sections of such fragments examined metallographically often show a light etching layer on parts of the fracture surface. As shown in Fig. 2 this layer is sometimes porous, while at other times the white layer is not markedly different in appearance from the white-etching layers produced by highly localised (adiabatic) shear.*

To confirm the cause of the phenomenon, and to further examine its nature, a small experimental investigation was made of the effects that a high velocity gas wash has on previously characterised fracture surfaces.

EXPERIMENTS AND RESULTS

A simple method was devised to allow the gaseous products of a detonated explosive to wash over steel fracture surfaces, and is illustrated in Fig. 3. Four fractured tensile specimens were screwed into the steel

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* Metallographic examinations of the structures near fracture surfaces are usually best carried out using taper sections. Although deliberate taper sections were not taken of these specimens, because of the natural unevenness of fragments, some cross-sections exhibited surfaces at taper angles to the fracture and so enhanced the magnification of the surface layers.

slab, with fracture surfaces uppermost, and a cylindrical piece of high explosive (55RDX/45TNT/1BW) was supported above them. The whole arrangement was supported on a piece of soft board over a water-filled pit.

The HE was detonated from the top with an EBW (exploding bridge wire) detonator which caused detonation products to wash over the fracture surfaces. Most specimens remained in the plate which was thrust into water from which it was subsequently recovered.

The matching halves of the tensile specimens were used to characterise the fracture surfaces prior to test in a scanning electron microscope (SEM). Typical fracture features are shown in Fig. 4.

After the gas-washing experiment the specimen surfaces were examined in the SEM, and Fig. 5 shows examples of features very similar to those seen on some fragment fractures as illustrated in Fig. 1. Gas washed fracture features were compared with those of the unwashed fractures and examples corresponding to those of Fig. 4 are shown in Fig. 6.

After SEM examination the gas-washed fractures were nickel plated and then mounted and metallographically polished using the taper section technique. These sections were examined optically and representative features are shown in Fig. 7. Two white-etching layers were usually produced at the fracture surface. The outer layer contained many holes, while the inner layer appeared to contain little or no porosity. Where only one layer could be identified, this was not porous.

Knoop low-load hardness measurements made on gas-wash-affected layers of the specimen showed that in general the inner layer was about 300 points higher in hardness than the matrix. Hardnesses of the layer were in the range 700-850 HK0.100 whereas the matrix hardnesses were in the range 350-550 HK0.100.

Two of the gas-washed specimens used for SEM examination were tempered in a salt pot at 350°C for 1 hour. After nickel plating and mounting the metallographically-sectioned and nital-etched specimens showed that the previously white etching layer now etched more darkly than the matrix (Fig. 8). Knoop hardness measurements were very difficult to perform on these specimens as the layer was quite narrow and seemed porous. However, indications were that the layer was slightly harder than the matrix.

Investigation of the surface layers with an electron-probe microanalyser indicated that they were substantially Fe-C-Mn alloys similar to the matrix material. Oxygen was not present in quantities which would be present if the layers were oxide. (It was possible that an oxide would form as a result of a reaction with the explosive gases or due to atmospheric corrosion).

DISCUSSION AND CONCLUSIONS

The gas-wash experiments produced features on fracture surfaces which have the essential characteristics of those observed on some fragments produced by explosive fragmentation.

In both cases the features are often associated with two white-etching surface layers. Their width, hardness, tempering behaviour and composition indicate that the layers resulted from rapid heating by the detonation gases, followed by rapid cooling or quenching by heat loss into the bulk matrix to give a structure consisting essentially of untempered martensite. The characteristics of the inner layer are not unlike those of adiabatic shear traces. The outer layer was indicative of superficial melting with gas porosity occurring on solidification.

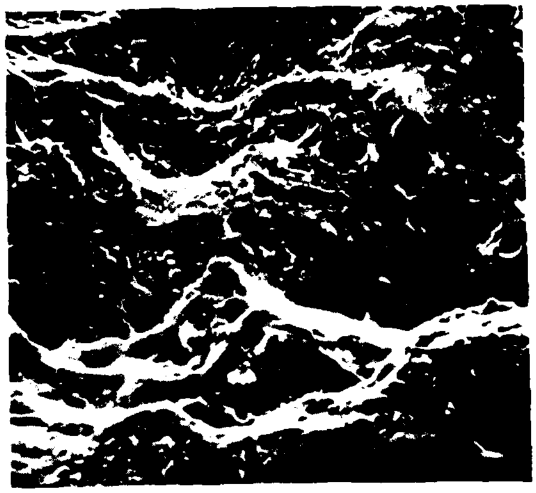
Not all, in fact relatively few, fracture surfaces produced by explosive fragmentation show gas-wash effects. In other work (1), high-speed photography shows gaseous products issuing from cracks in the surface of internally detonated bodies before the separation of discrete fragments. It must be concluded therefore that the time between first emergence of the products, and formation and ejection of the fragments is too short to enable the gas-wash features to be produced on most fracture surfaces.

ACKNOWLEDGEMENTS

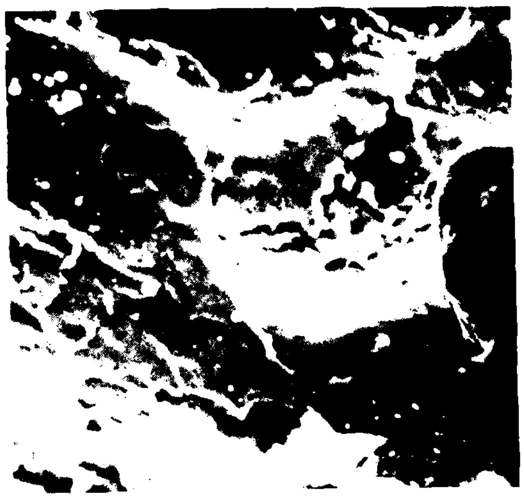
The author wishes to thank Mr. P. Humphris, Explosives Development Group, for his advice on the experimental set-up.

REFERENCE

1. Banks, E.E. (1968). "The Ductility of Metals under Explosive Loading Conditions". J. Inst. Metals 96, 375.

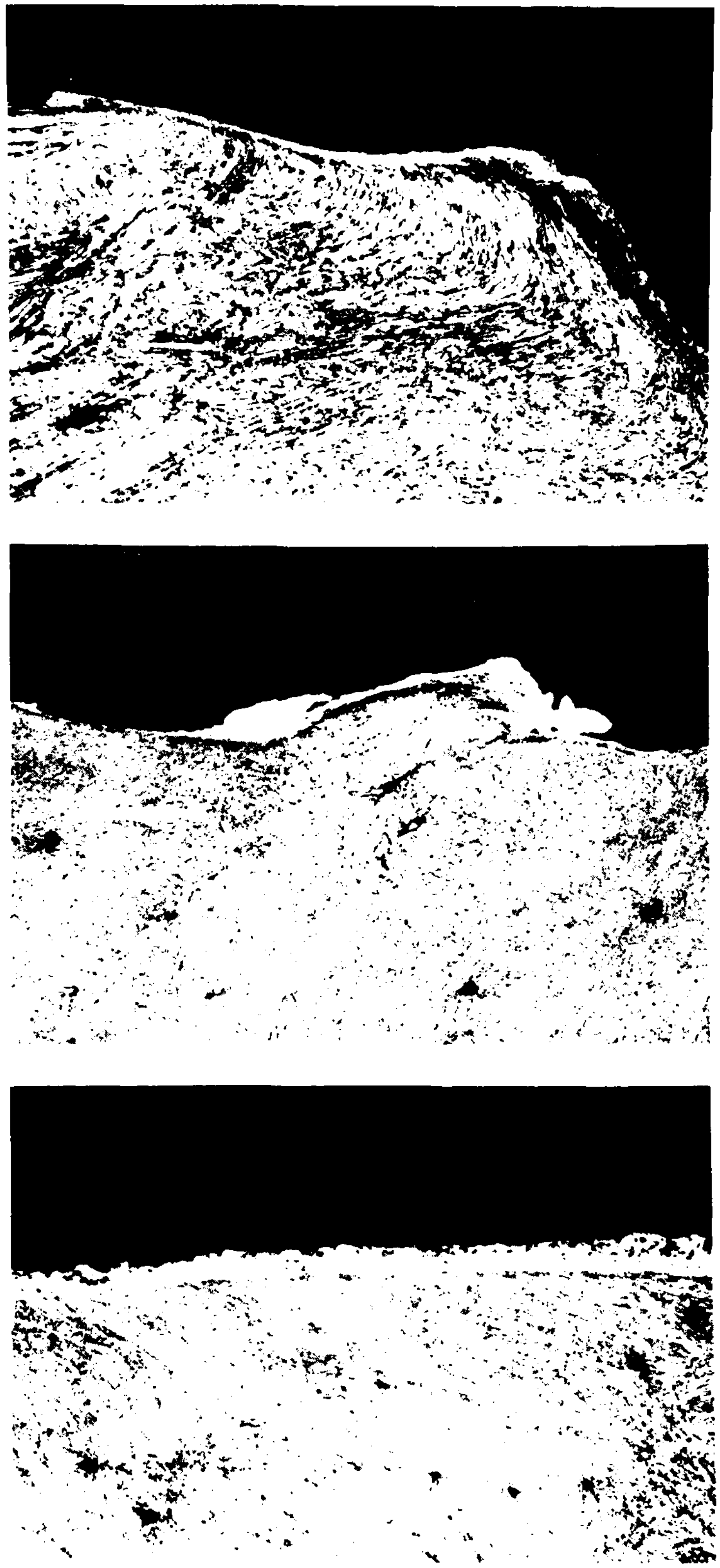


(a) x 430



(b) x 1600

FIG. 1 - Scanning electron micrographs of fracture surfaces of fragments demonstrating effect often ascribed to gas washing.



(a) x 500

(b) x 500

(c) x 500

FIG. 2 - Cross sections of fragment fracture surfaces showing white etching layers probably due to gas washing.

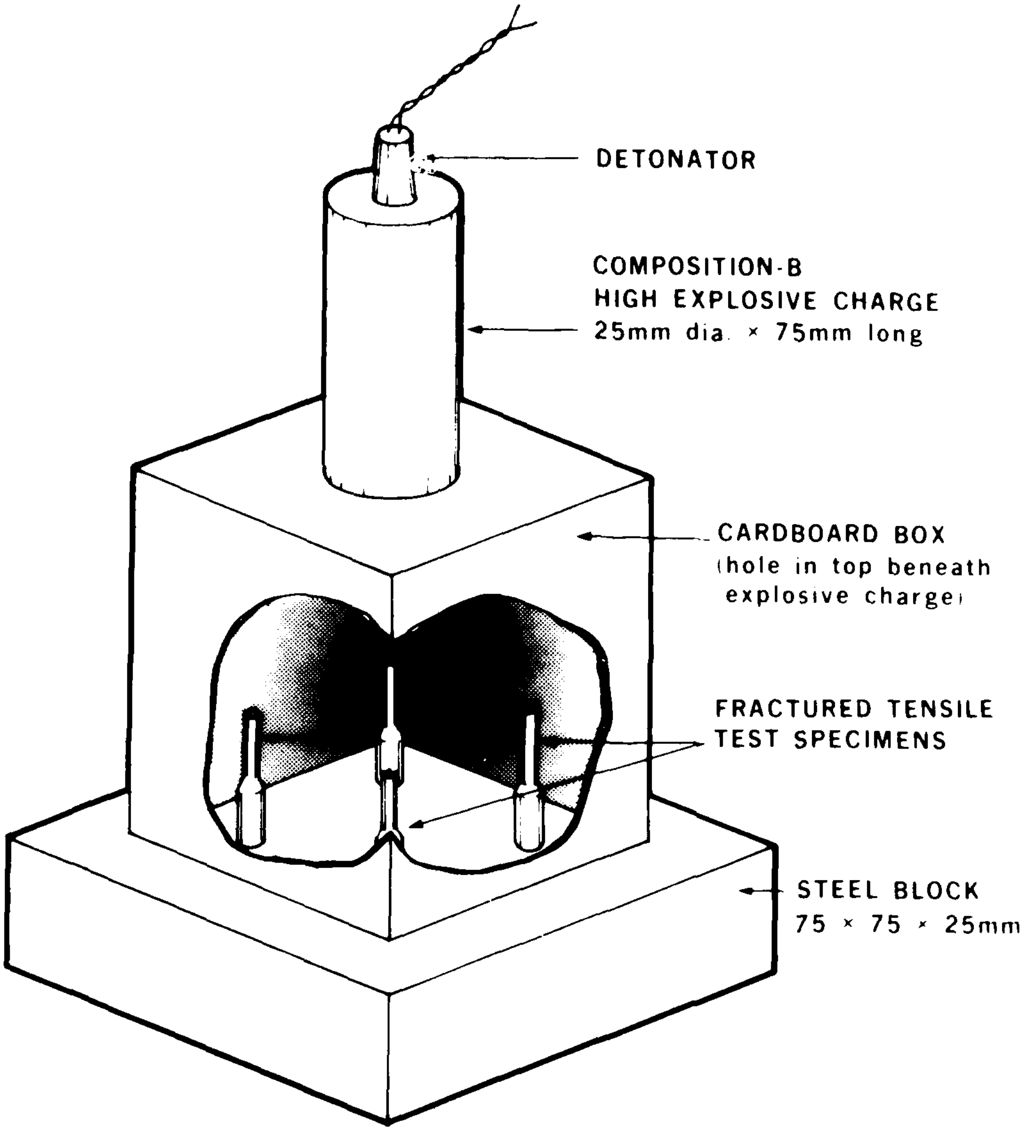
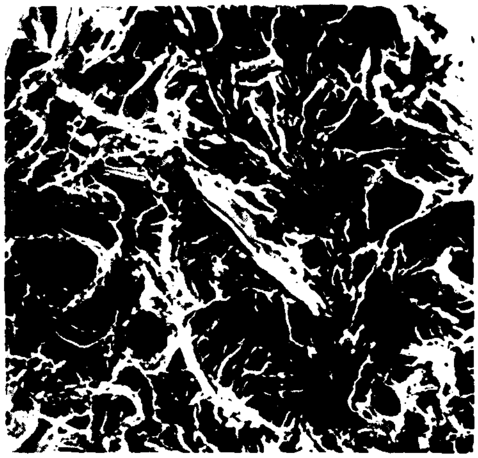
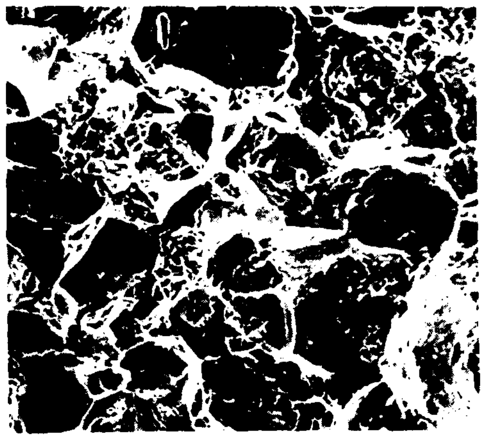


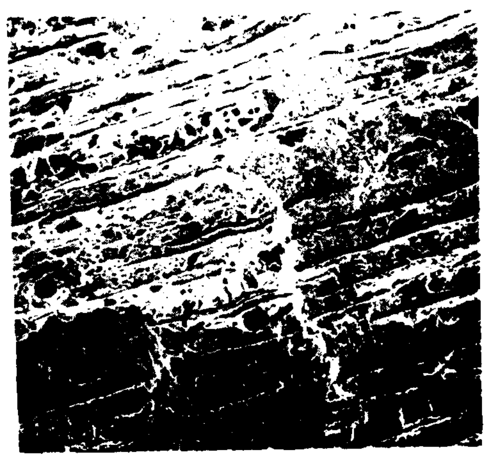
FIG. 3 - Experimental arrangement for gas wash experiment.



(a) x 450

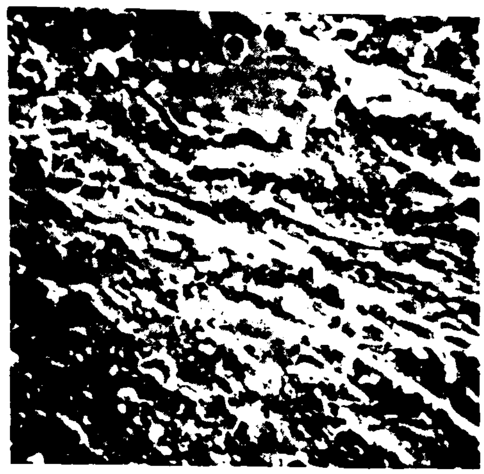


(b) x 440

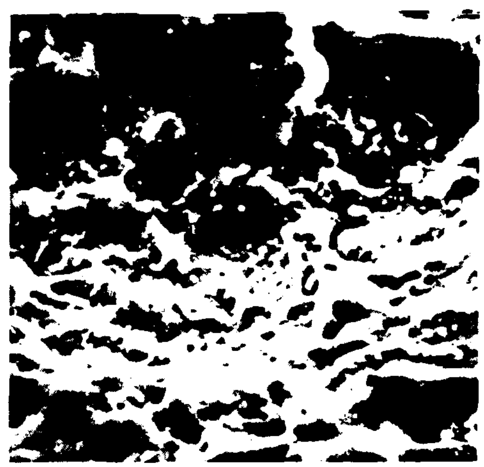


(c) x 90

FIG. 4 - Scanning electron micrographs of fracture surfaces of tensile test specimens.

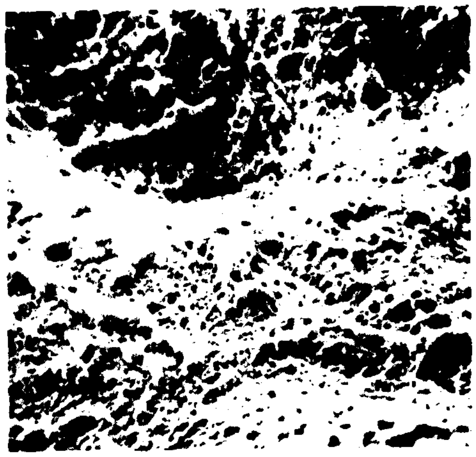


(a) x 1750

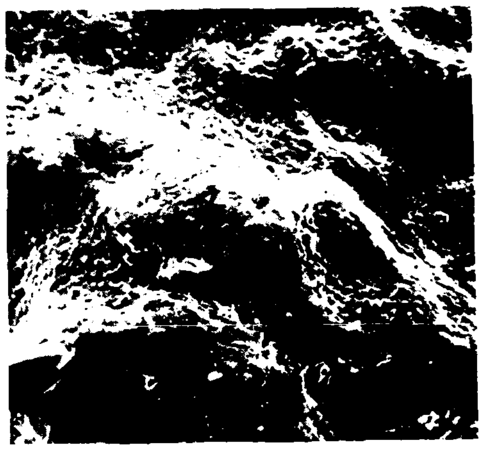


(b) x 1850

FIG. 5 - Examples of features observed after gas washing of tensile test specimens, (SEM's), cf. Fig. 1.



(a) x 440

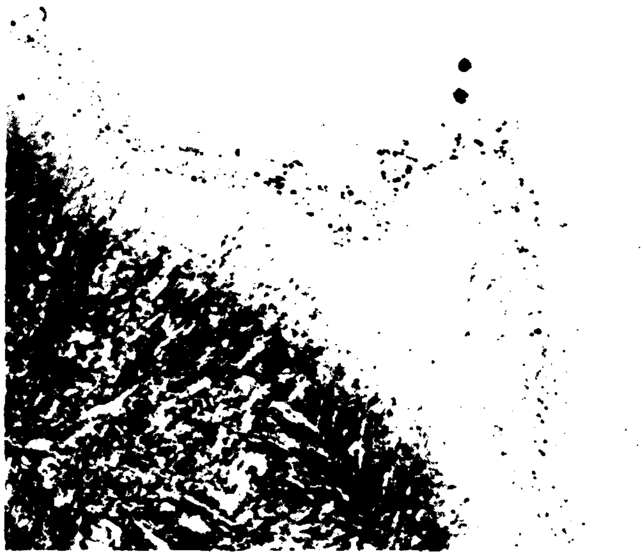


(b) x 180

(c) x 50

FIG. 6 - Gas washed fracture surfaces from matching halves of specimens illustrated in Fig. 4.

(a) x 1000



(b) x 1000

FIG. 7 - Optical micrographs showing white etching layers produced by the explosive gas washing. These specimens have been taper sectioned but because of the unevenness of the fracture surface, the taper ratio cannot be determined.

x 1000

FIG. 8 - Cross section of gas washed fracture after tempering at 350°C for 1 hour. The surface layer now etches more darkly than the matrix.

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